

Kerosene Fire Experiments

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Contents

- Goals and work program
- Available results from German research
- First results from literature
- First actual experimental results
- Summary and conclusions

Goals and Work Program

- Goals
 - ◆ Estimation of basic data for simulating kerosene fires under different boundary conditions
 - ◆ Exemplary calculation of fire effects for selected kerosene fire scenarios
 - ◆ Rough estimate of the risk of explosion in case of sprayed kerosene and the consequences
- Work program
 - ◆ Kerosene pool fire experiments
 - ◆ Comparison of the experimental results with data from literature
 - ◆ Definition of fire scenarios outside as well as inside of buildings
 - ◆ Fire simulations
 - ◆ Rough estimate of the consequences of explosions

Results of German Research

- SR 144/1 experiments (1982-1985)
 - ◆ Experiments with oil fire loads in pans of 2 m² with and without continuous feeding of oil and different ventilation conditions
 - ◆ Fire compartment temperatures 1080 – 1370 °C
 - ◆ Burning rate 1,35 – 3,15 kg / m²·min
 - ◆ Energy release rate up to 2,2 MW / m²
- HDR fire experiments (1986-1992)
 - ◆ Experiments with oil fire loads in pans of 1 - 3 m² with feeding of oil for different room geometries
 - ◆ Fire compartment temperatures up to 1500 °C
 - ◆ Burning rate up to 3,6 kg / m²·min
 - ◆ Energy release rate up to 2,6 MW / m²

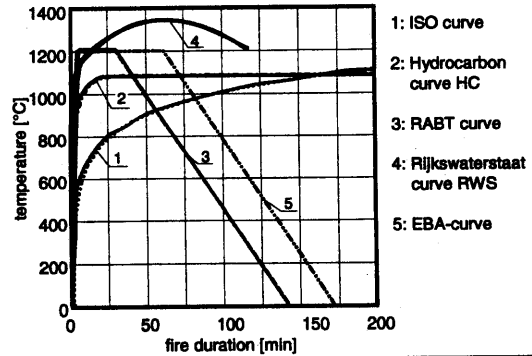
Results from Literature (1)

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- Hydrocarbon fires
 - ◆ Scaled offshore fire experiments (SINTEF, Norway)
 - ◆ Fast fire spreading on the pool surface
 - ◆ Energy release rate 1,7 – 4,9 MW / m²
- Fluid fires in general
 - ◆ In case of pool fires with sufficient oxygen, medium "burning velocity" of approx. 3 mm/min
 - ◆ Energy release rate of kerosene depending on the heat release approx. 11,7 kWh / kg, i.e. 1,4 MW / m²

Time-temperature Curves

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Results from Literature (2)

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- Kerosene pool fire experiments
 - ◆ Open kerosene pool fires (SANDIA, USA)
 - ◆ 280 m² pan, 15 cm water + 25 cm kerosene
 - ◆ Fire spreading on the pool surface within 20 s
 - ◆ Burning rate 4,1 – 4,9 kg / m²·min (effects of wind)
 - ◆ Maximum temperatures 1300 – 1500 °C
 - ◆ Heat flux density at a wall up to 4,5 m height 100 – 130 kW / m²
- Kerosene explosion experiments
 - ◆ Laboratory scale (Aeronautical Laboratories, USA)
 - ◆ Flame point and explosion points uncertain (composition of kerosene not well known)

Recent German Approach

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- Kerosene pool fire experiments
 - ◆ Kerosene experiments (February 2002) in steel pans of 0,5 m², 1,0 m² und 2,0 m² and kerosene level of 10 cm and 3 cm
 - ◆ Measuring burning rate, temperature and radiation heat in the fire compartment
- Definition of relevant fire scenarios
 - ◆ Pool fires outside buildings
 - ◆ Fires with combinations of kerosene and other fire loads inside buildings; comparison with former experiments
- Fire simulations
 - ◆ Comparison of calculations with different types of codes

**Aviation Fuel Fire Experiments
Foreseen in Germany for 2002/03**

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- Kerosene pool fire experiments
 - ◆ Inside confinements
 - ◆ Outside buildings
- Combustible mixtures from fuel gas and air inside confinements with the potential for deflagration / detonation
- Fuel spray formation and fireball outside buildings

**Kerosene Pool Fires -
Goals of the Experiments**

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- Basic data for fire simulations
 - ◆ Burning rate
 - ◆ Energy release
 - ◆ Flame temperature
 - ◆ Heat flux density
- Consideration of dependencies
 - ◆ Pool size
 - ◆ Pool height
 - ◆ Underground material (steel/concrete)

**Kerosene Pool Fires Inside
Confinements**

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- Room size ($L \times W \times H = 3,6 \text{ m} \times 3,6 \text{ m} \times 5,8 \text{ m}$)
- Pool size: 0,5 m²; 1,0 m²; 2,0 m²; 4,0 m²
- Pool height: 3 cm; 10 cm
- Ventilation
 - ◆ Ventilation controlled
 - ◆ Fire load controlled
- Effects of structures and equipment
 - ◆ Concrete, steel, etc.
 - ◆ Heat sinks (water tank)
 - ◆ Cable trays in case of low fire loads

**Measuring Equipment for
Kerosene Pool Fires**

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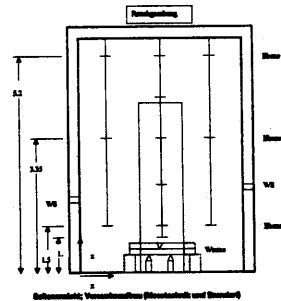
- Burning rate by mass loss rate
- Temperatures
 - ◆ Plume
 - ◆ 3 levels above the fire
 - ◆ Inside and on structures and heat sinks
 - ◆ On cable surface (fire inside compartment)
- Velocity
 - ◆ Via Plume height and wind velocity
 - ◆ In the off-gas line (fire inside compartment)
- Heat flux at different locations
- Gas analysis (O₂, CO₂ and CO)
- Heat camera

Experimental Layout, Measurements

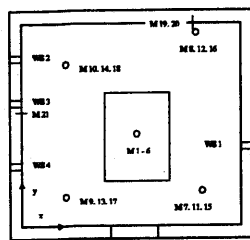
IBMB

- Fire compartment
 - ◆ Length 3,6 m
 - ◆ Width 3,6 m
 - ◆ Height 5,7 m
- Measurements
 - ◆ Plume temperature (6 locations)
 - ◆ Three measurement levels (4 locations)
 - ◆ Surface temperature (3 locations)
 - ◆ Heat flux (4 locations)
 - ◆ Mass loss

Fire Compartment Layout (1) IBMB



Fire Compartment Layout (2) IBMB



Kerosene Pool Fires Outside Buildings IBMB

- Pool size: 0,5 m²; 1,0 m²; 2,0 m²; 4,0 m²; 16 m²
- Filling level: 10 cm
- Ventilation
 - ◆ No wind
 - ◆ Effects of wind
- Reference equipment at a wall
 - ◆ Concrete, steel, etc.
 - ◆ Heat sinks (e.g. water storage tank)

Combustible Gas Air Mixtures Inside Confinements

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- Formation of combustible mixtures from kerosene and air inside nearly closed confinements
 - ◆ Formation of gas clouds
 - ◆ Spreading of gas and formation of mixtures
 - ◆ Combustion/explosion process (deflagration, detonation, DDT)

Combustible Gas Air Mixtures Inside Confinements

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- Steps of the investigations:
 - ◆ Comparison of data for kerosene and hydrogen
 - ◆ Comparison of combustion process of kerosene and hydrogen
 - ◆ Specification of additional experiments (PTB)
 - ◆ Status of the hydrogen modeling
 - ◆ Applicability of available models for fuel gas combustion/explosion (flame acceleration, possibility of DDT)
 - ◆ Exemplary analysis for model validation and applicability

Aviation Fuel Spraying And Fireball Outside Buildings

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Questions:

- How far will the fuel been distributed after the impact?
- What is the droplet size of the fuel droplets?
- Which amount of fuel is directly burnt in the fireball, which amount is available for a pool fire?
- What are the effects and consequences of a fireball?

Fuel Spraying And Fireball Outside Buildings

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Investigation methods

- Fuel spraying ⇒ impact experiments
 - ◆ Depending on velocity, potential targets, amount, etc.
 - ◆ Droplet spectra, distribution
- Combustion ⇒ ignition experiments and modeling
 - ◆ Amount of directly burnt droplets
 - ◆ Fireball characteristics, potential for scale up
- Comparison with literature including reports on aircraft crashes

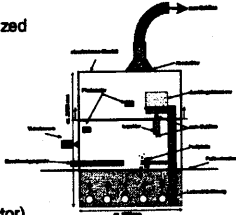
⇒ Model for fireball effects and amount of fuel left

Fuel Spraying And Fireball Outside Buildings

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Impact experiments with fluids (ITA Hannover)

- Experimental facility
 - ◆ Acceleration of pressurized air up to ~ 100 m/s
 - ◆ Video observation
 - ◆ Variation of velocity, fuel amount, target
- Droplet diagnosis
 - ◆ Total mass / surface (gravitational/optical)
 - ◆ Size distribution (Impactor)
 - ◆ Velocity (PDA)
- First experiments foreseen for July 2002



Fuel Spraying and Fireball Outside Buildings

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Ignition Experiments (BAM/PTB) and Fireball Modeling

- Ignition experiments
 - ◆ Fuel spray ignition (droplet spectra analogous to ITA-experiments)
 - ◆ Fireball characteristics
 - ◆ Amount of fuel for pool fire
- Numerical simulations
 - ◆ Model validation with experiments
 - ◆ Scaling up from small scale to real scale experiments

Summary and Conclusions

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- Goals of the activities
 - ◆ Gaining important basic data with respect to kerosene as used in Germany
 - ◆ First rough estimates of the potential consequences of kerosene fires outside and inside of buildings
- Recent status
 - ◆ Analysis of experimental data from German as well as other institutions
 - ◆ Kerosene pool fire experiments inside buildings)
- Continuation of work
 - ◆ Definition and simulation of fire scenarios
 - ◆ Identification of the significant parameters
- Expected results
 - ◆ Statements with respect to the significance of kerosene fires
 - ◆ Assumptions for further investigations